Tackling Water Pollution by Tracking Phosphorus in Soils

At the National Synchrotron Light Source (NSLS), scientists have determined how the element phosphorous, a plant fertilizer and surface water contaminant, adheres to two common soil minerals. This study will help to determine how phosphorus migrates from soils to water bodies and which types of soil are better at holding phosphorus – findings that may help to define future soil management policies and decrease the environmental impacts of phosphorous contamination.

The results appeared as the cover article in the March-April 2004 issue of the *Soil Science Society of America Journal*.

"Studying how soils hold phosphorus is necessary because soils are critical for food production and for removing environmental contaminants from water that flows into streams, rivers, lakes, and estuaries," explained Dean Hesterberg, a soil chemist from North Carolina State University who led the study. "However, soils are made up of very complex mixtures of minerals, and it is difficult to determine exactly how plant nutrients and contaminants bind in the soil."

"Therefore, preventing water pollution by managing soil phosphorous levels is often based on indirect approaches that measure how easily a portion of phosphorus can be pulled out of the soil, rather than on an understanding of how the phosphorus is chemically bound in the soil. Knowing the latter helps in more accurately predicting how environmental changes affect phosphorus release."

Phosphorus is commonly added to soils as fertilizers for agricultural crop production. "Phosphorus becomes an environmental concern when it is applied to soils in excessive amounts, as sometimes occurs when waste materials, such as animal waste, are used to fertilize crop soils," Hesterberg said. If the amount of phosphorus added to soils exceeds the plants' needs and the soil's holding capacity, he explained, then excess phosphorus migrates to rivers and lakes via runoff waters, and abnormally stimulates the growth of aquatic plants. The boom in plant growth depletes the waters' oxygen content, endangering fish and other aquatic plants, and deteriorating water quality.

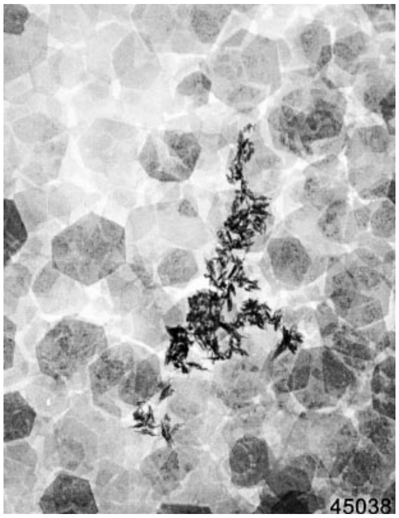
"This work was important because it showed that we can use x-rays to obtain more exact information on how phosphorus binds to different minerals that occur together, and to better understand how each mineral contributes to holding phosphorus in soils," he said. "This is necessary for developing better ways to manage many different soils so that phosphorus movement to waterways is minimized, and we can better evaluate how much phosphorus can be added to soils without causing environmental problems."

Phosphorus occurs at different concentrations in different types of soil, but soils rich in iron (iron oxide) and aluminum (aluminum oxide) minerals can hold more phosphorous. In this research, two such minerals, iron oxide-based ferrihydrite and aluminum oxide-based boehmite, were investigated to determine how phosphorus (in the form of phosphate, a phosphorus compound) is adhered, or "adsorbed," onto them, and to understand how phosphorus is distributed between both types of minerals in soils.

Clockwise (From left, top): Nidhi Khare, Dean Hesterberg, Shan-Li Wang, and Suzanne Beauchemin

Working at NSLS beamline X19A, the scientists tracked how much phosphate was held by each mineral. They determined how phosphate adsorbed onto ferrihydrite and boehmite by shining x-rays at soil samples containing just ferrihydrite, just boehmite, and mixtures of both. By looking at the unique patterns created as the x-rays emerged from each sample, the scientists were able to determine how much phosphate had adsorbed onto each mineral in the mixture based on data for the individual minerals.

The results show that, at low phosphate concentrations,



Transmission electron microscope image (50,000X magnification) of a mixture of iron- and aluminum-oxide minerals: hexagonal gibbsite [α-Al(OH)$_3$] platelets and aggregated, lathe-shaped goethite (α-FeOOH) particles. Iron and Al-oxides are considered the most important minerals for retaining phosphate in soils, but their relative importance as they coexist in soils is unclear.

ferrihydrite holds phosphate more strongly than boehmite. The researchers also found that at intermediate concentrations, each of these minerals adsorbs phosphate about equally well. This information will help determine how phosphate dissolves and migrates within different soils, which may contribute to the development of soil management policies aimed at minimizing the effect of phosphorus on the environment.

The other researchers who participated in this study are Dr. Nidhi Khare, a former Ph.D. student in Hesterberg's lab and the lead author, now a post-doctoral researcher at the University of Wyoming; Dr. Suzanne Beauchemin, from Natural Resources Canada; and Dr. Shan-Li Wang, now an Assistant Professor at National Chung Hsing University in Taichung, Taiwan.

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—Laura Mgrdichian